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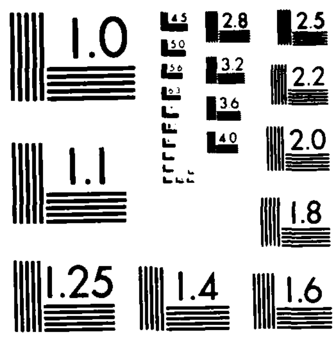
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INTERNATIONAL SYMPOSIUM ON CORRELATION AND POLARIZATION IN ELECTRON-ATOM COLLISIONS

AD-A174 992

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Pasadena, California

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PROGRAM

International Symposium on Correlation and Polarization in Electron-Atom Collisions

Pasadena, California

August 1-2, 1985

THURSDAY, August 1

8:25 - 8:30 a.m.	Welcome, S. Trajmar
8:30 - 9:45	K. Blum, University of Munster What We Have Learned From e-γ- Coincidence Experiments
9:45 - 10:25	J. Williams, University of Western Australia, Perth Time Development of Stark Mixed Atomic Hydrogen States
10:25 - 10:55	COFFEE BREAK
0:55 - 11:35	G. Baum, University of Bielefeld Polarized Electron-Polarized Atom Collisions
11:35 - 12:15	G. F. Hanne, University of Munster Polarization In Electron Collisions With Heavy Atoms
12:15 - 1:30	LUNCH
1:30 - 2:10 p.m.	O. Berger, University of Munster Elastic Scattering of Polarized Electrons From Mercury and Xenon For Complete Evaluation of the Scattering Amplitudes
2:10 - 2:50	M. S. Lubell, City College of CUNY The Three-Body Interaction With Long Range Forces: Spin Tagged Electron-Atomic-Hydrogen Scattering
2:50 - 3:20	COFFEE BREAK
3:20 - 4:00	D. Golden, University of Oklahoma Correlation in Electron-Sodium Scattering
4:00 - 4:40	M. Kelly, NBS Electron Atom Collision Studies Using Optically State Selected Beams
4:40 - 5:00	K. Rubin, City College of CUNY Anomalous Effects In Very Small Angle Electron-Potassium Differential Scattering Measurements

FRIDAY, August 2

8:30 - 9:45 a.m.	I.V. Hertel, University of Berlin Alignment and Orientation In Collision Processes - What We have Learned So Far
9:45 - 10:25	K. Bartschat, University of Munster Electron Scattering On Heavy Atoms
10:25 - 10:55	COFFEE BREAK
10:55 - 11:35	H. Nishimura, Niligata University Electron-Photon Angular Correlation Parameters For KR: $5S[3/2]^o_1\ ^1P_1, 5S^1[1/2]^o_1\ ^1P_1$, Xe $6S[3/2]^o_1\ ^3P_1$, $6S^1[1/2]^o_1\ ^1P_1$ and H_2: $C^1\pi_u$ Excitation
11:35 - 12:15	J. W. McConkey, University of Windsor Electron-Photon Coincidence Experiments Using Molecular Targets
12:15 - 1:30	LUNCH
1:30 - 2:10 p.m.	B. Jaduszliwer, The Aerospace Corporation Some Physics With State Selected Sodium Beams
2:10 - 2:50	P. J. O. Teubner, Flinders University Coherence and Correlations In Electron Collisions With Metal Vapors
2:50 - 3:20	COFFEE BREAK
3:20 - 4:00	M. C. Standage, Griffith University Application Of Stepwise Excitation Techniques To Polarization Correlation And Super-Elastic Scattering Studies of Electron-Atom Collisions
4:00	H. Kleinpoppen, University of Stirling Concluding Remarks

END OF CONFERENCE

What we have learned from e-γ-coincidence experiments

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In this paper the present status of e-γ-coincidence experiments will be reviewed. Basically, coincidence techniques allow one to study observables which vanish in non-coincidence experiments. Some of these observables have been extensively studied (orientation, alignment resp. λ, χ-parameters), others require more sophisticated experimental methods, for example

i) ε, Δ-parameters for spin-dependent scattering experiments (or excitation by heavy particles where the projectiles have been excited)

ii) parameters describing coincidence experiments with polarized electrons

iii) observables characterizing even-odd parity coherences in e-H-scattering and their time evolution in external fields.

The physical content of these parameters will be discussed with the emphasis on the qualitative aspects. Some of these observables are sensitive only to certain atomic interaction. Their determination can therefore be useful in disentangling the influence of various interactions on the process observed.

Some closely related results from other fields than electron-atom scattering (heavy particle collisions, scattering on surfaces) will also be discussed.

TIME DEVELOPMENT OF STARK MIXED ATOMIC HYDROGEN STATES

L. Heck and J. F. Williams

Physics Department
University of Western Australia, Perth, Australia

Recent experimental developments have produced electron-photon coincidence resolving times of less than 10 nanoseconds and a circular polarization analyzer for 121.6NM photons. Measurements using these features have been made for stark mixed N=2 states of atomic hydrogen for an electron energy of 350 eV and a scattering angle of about 3 degrees. The polarization analyzer is located normal to the scattering plane and longitudinal static electric field of 250 volts per cm.

The time development of the excited mixed state under the influence of the electric field is calculated using the density matrix formalism of Blum. The S and P (half and three halves) state gives rise to beat periods of 0.1 and 0.67 nsec approximately due to fine structure and the stark effect, respectively. Born approximation values are used for the state multipoles of the initial system. From the resulting formulae for intensity and stokes parameters of the emitted photons, experimental conditions are deduced to get optimal visibility of the stark modulation.

Polarized electron - polarized atom collisions

G. Baum, W. Raith, U. Sillmen, and H. Steidl
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Fed. Rep. of Germany

A report on the status of spin-resolved elastic and inelastic collision studies will be given. Experiments with crossed beams, both polarized, allow a direct observation of the relative difference of singlet (σ_s) and triplet (σ_t) scattering. Measurements of the spin asymmetry A, $A = (\sigma_s - \sigma_t)/\sigma_s + 3\sigma_t)$, on lithium will be presented. At scattering angles of $107{,}5^\circ$ and 90° we measured A for elastic scattering and inelastic 2s-2p scattering from 1 eV above threshold to about 10 eV. A description of the experimental method is given elsewhere[1]. The data will be compared with a recent 5-state close coupling calculation[2], which shows in general very good agreement, and with results of different theoretical approaches. Experimental progress on producing highly spin polarized beams of cesium and helium (2^3S) will be discussed and the future directions of our work with those beams indicated.

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Polarization in electron collisions with heavy atoms

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The use of intense sources of polarized electrons and the further development of experimental techniques such as laser excitation or electron-photon coincidence measurements opens new possibilities for studying electron-atom collisions. The role that various mechanisms play in such collisions (e.g. Coulomb interaction, collisional orientation and alignment, spin-orbit interaction, exchange) can now be studied in detail and compared with theoretical models.

Of particular interest are targets that have $\langle\vec{S}\cdot\vec{L}\rangle \neq 0$, i.e. non-vanishing orbital and spin angular momentum before or after scattering. In such a collision system this target spin-orbit interaction will transfer orbital angular momentum orientation into spin orientation and vica versa. If exchange collisions are involved this will result in e.g. spin polarization of scattered electrons /1/ or circular polarization of light emitted after excitation by polarized electrons. In electron collisions with heavy atoms the continuum spin-orbit interaction may cause additional polarization.

It is the purpose of this talk to give simple pictures of the spin-dependent effects and to demonstrate their relative importance by presenting some experimental results obtained in Münster in the last two years. The collision systems under study are elastic and inelastic scattering of electrons from Hg and Pb.

/1/ G.F. Hanne, Comments At. Mol. Phys. 14 (1983) 163

ELASTIC SCATTERING OF POLARISED ELECTRONS FROM MERCURY AND XENON FOR COMPLETE EVALUATION OF THE SCATTERING AMPLITUDES

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The elastic electron scattering from spinless atoms can be described completely by two complex scattering amplitudes if Coulomb interaction and spin-orbit interaction in the continuum are taken into account. Complete elastic scattering experiments are feasible in the sense that the moduli and the relative phase of the two scattering amplitudes can be determined /1/.

Experiments in which the differential cross section or the Sherman function S are measured do not contain all the information on the scattering process due to the fact that unpolarised electrons are scattered and the effect of the electron spin in the scattering process is not accessed completely. The missing information can only be obtained by scattering polarised electrons and measuring the additional parameters T and U describing the change of the polarisation in the scattering plane /2/.

In the special case where the primary polarisation lies in the scattering plane , as in our experiment, the polarisation $\vec{P}'$ of the scattered electrons can be described by

$$\vec{P}' = S\hat{n} + T\vec{P} + U(\hat{n} \times \vec{P}) \qquad (1)$$

where $\hat{n}$ is the unit normal vector of the scattering plane.

In the experiment we report here the angular dependence of the polarisation parameters S, T and U has been measured at various fixed energies between 25 eV and 350 eV for mercury and xenon. The polarised electrons are produced in a GaAsP source. A rotatable deflection system allows to vary the scattering angle continously. The spin polarisation of the elastically scattered electrons is measured by a high energy Mott detector. Two pairs of counters in the Mott detector

allow a simultaneous analysis of the transverse polarisation components. From the measured data the polarisation parameters S, T and U are derived.

The experimental results are shown in comparison with several theoretical calculations /3/, /4/, /5/, /6/. From the polarisation parameters S, T and U together with the absolute differential cross section, which has been investigated for xenon by different groups, a complete evaluation of the scattering amplitudes is feasible and will be presented in terms of the moduli and the relative phase. From this evaluation it follows, that discrepancies between theory and experiment which are found in the polarisation parameters S, T, U and in the differential cross section can also be seen in the moduli and the relative phase of the scattering amplitudes.

For mercury, however, the complete evaluation of the scattering amplitudes is not yet possible, because in the energy range covered by this experiment no absolute differential elastic cross section are available, but measurements are in progress in Münster.

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THE THREE-BODY INTERACTION WITH LONG-RANGE FORCES: SPIN TAGGED ELECTRON-ATOMIC-HYDROGEN SCATTERING

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The three-body problem has long provided fascination for physicists, since it appears to be an extremely simple system and yet defies solution in closed analytic form. In the case of nuclear and particle physics, successful approximation methods were developed quite early, in part because the short-range nature of the strong interaction enables a truncated basis set to be developed with relative ease. In the case of electromagnetic physics, however, the problem is infinitely more complex, because the long-range nature of the electromagnetic interaction makes the choice of basis set truncation much more ambiguous.

Within recent years, a number of three-body atomic or quasi-atomic systems have become the subject of detailed experimental investigation. These have included the H^- ion, the e^--H and e^+-H collision systems, and the $\mu^+e^-e^-$ ion. The e^--H collision system, in particular, in preliminary studies with polarized beams has already revealed substantial descrepancies with theoretical predictions.

In this talk I will review the virtues of spin-tagging as a means of providing detailed information about the scattering process. I will further summarize the results of the preliminary probes of e^--H ionization and elastic scattering and discuss the status of the current studies. In conjunction with this last topic I will indicate how recent technological advances in polarized-electron and hydrogen source development have enhanced the capabilities of such studies. I will conclude with some thoughts on future prospects for e^--H as well as e^+-H collisions.

Correlation in Electron Sodium Scattering

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In the past we have used electron-photon coincidence techniques to study the electron-impact excitation of the 2'P state of helium.[1,2] Since fine and hyperfine structure need not be considered in this excitation, only three independent parameters are needed to completely describe the process. However, the non-zero spin of the alkali atoms requires the introduction of additional scattering amplitudes, to allow for spin dependent effects.[3,4]

We are in the process of experimentally determining the various conbinations of scattering amplitudes and phases in the electron impact excitation of the $3\,P_{1/2,3/2}$ state in sodium. The current program consists of three stages. The first stage is to determine absolute differential cross sections for the excitation of the 3 P state over the energy range from 4 to 100 eV, and to compare it with previous experimental and theoretical results. Our results below 10 eV are the first obtained in that range.

We have also started work on the second stage of the program. In this we examine the excitation using the electron photon coincidence technique. The study of the polarization of the coincidence signal with the photon detector out of the scattering plane, using a Stokes parameter analysis, gives all the scattering amplitudes, except the one relating to spin exchange, as well as a convenient test of the coherence of the excitation.[5] An additional measurement of the polarization, done with the photon detector in the plane, provides the scattering amplitude related to spin exchange. With this technique all the experimentally observable scattering parameters can be determined.

The third stage involves the use of similar techniques, but we shall use lasers to optically pump a particular F, M_F hyperfine level of the ground state of the atom and thus determine state to state hyperfine amplitudes and phases.

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ELECTRON ATOM COLLISION STUDIES USING OPTICALLY STATE SELECTED BEAMS*

M. H. Kelley, J. J. McClelland, and R. J. Celotta

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National Bureau of Standards
Gaithersburg, MD 20879

Our efforts in the past year and a half have concentrated on two different areas of our program to study spin-dependent effects in collisions between spin-polarized electrons and spin-polarized atoms. First, we undertook a rather extensive investigation, both experimental and theoretical, of the laser optical pumping process with particular emphasis on certain details applicable to the preparation of a spin-polarized beam of sodium atoms. Second, we began a series of measurements to study spin-dependent effects in superelastic scattering from the $3P_{3/2}$ state in sodium.

The study of optical pumping was prompted by the necessity of improving our knowledge of the degree of atomic spin polarization achievable by laser optical pumping. The theoretical investigation consisted of numerically integrating the equations describing the time development of the atomic density matrix to give time evolution of the populations of each of the hyperfine sublevels. This approach has the advantage over the more common rate equation treatment that coherence phenomena in the transient period before the optical pumping reaches a steady state, such as Rabi oscillations, can be correctly treated. The resulting time-dependent level populations were integrated over transit time distributions to predict the state distributions expected in our experimental arrangement.

The primary experimental observables were the degree of polarization of the F=2 ground state and the fraction of atoms transferred to the F=1 ground state during the pumping process. Each was determined from observations of flourescence light arising from a second laser in a probe region located downstream in the atomic beam from the optical pumping region. The F=2 ground state polarization was determined by observing the polarization of resonance fluorescence with the probing laser tuned to the $3S_{1/2}$ (F=2) to $3P_{3/2}$ (F=3) transition. The change in the F=1 level population was determined by observing the fluorescence in the probe region with the probe laser tuned to the $3S_{1/2}$ (F=1) to $3P_{1/2}$ (F=1) transition and detecting the change in that fluorescence due to the presence of the primary laser in the optical pumping region. Reasonable agreement was found between experiment and theory. These results indicate that an atomic spin polarization of 0.609 +/- 0.018 can be reliably and reproducibly achieved in sodium by laser optical pumping.

We have also begun a series of measurements to determine the spin-dependence in superelastic scattering of electrons from excited sodium. In these measurements, a beam of polarized electrons from a negative electron affinity GaAs polarized electron source intersects the atomic beam in the

optical pumping region which is illuminated with laser light tuned to a particular hyperfine transition in sodium. The electrons superelastically scattered to some angle are separated from the elastic and inelastic electrons by a retarding field analyzer and detected with a channeltron. The electron energy is variable between 2 and 40 eV and the angular range is from 10 to 35 degrees. The atoms are excited with either circularly polarized light, to produce spin polarized and oriented atoms, or with linearly polarized light, to produce aligned atoms with no spin polarization.

The scattered electron intensity is measured for electron spin polarizations up or down with respect to the horizontal scattering plane. These s attering intensities are combined to determine the spin asymmetry, which is defined as the difference between the up and the down count rates normalized to their sum. This spin asymmetry is measured as a function of incident electron energy, scattering angle, and the polarization of the incident optical pumping laser. For circularly polarized optical pumping light we measure the spin asymmetry as a function of the direction of the atomic orientation. For linearly polarized light we measure the spin asymmetry as a function of the angle that the excited P state makes with respect to the incident electron direction. Spin asymmetries as large as 0.20 are observed.

*Work supported in part by U.S. Department of Energy, Office of Basic Energy Sciences, Division of Chemical Science.

COHERENCE PROPERTIES OF PARTICLE BEAMS

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Experimental data, obtained using the atom beam recoil technique, will be presented for the scattering of low energy electrons from potassium atoms at extremely small atomic recoil angles (of the order of 10^{-4} rad.), within the shadow of the atom beam. Measurements of the fraction of atoms scattered as a function of the position of the detector, within the region of the incoming atom beam, show an oscillatory structure which cannot be accounted for by the usual plane wave description of the scattering. An explanation of these results will be suggested which involves certain coherence properties of the colliding beams. It will be shown that these coherence properties can be related to the off diaganol elements of the density matrix describing the beams.

"Alignment and Orientation in Collision Processes - What we have learned so far"

N.A. Andersen[*], J. Gallagher[x] and I.V. Hertel[+]

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The talk will summarise the present state in our efforts to introduce a common and physically transparent framework to coherence and correlation studies in e-atom and heavy particle excitation of outer shells with a planar symmetry. We are currently reevaluating the about 500 papers which report experimental and theoretical data on alignment and orientation parameters, supplemented by a large body of mainly theoretical data from most recent private communications by various groups. We will use a set of illustrative parameters which are directly accessible to experiment along the lines described by Hermann and Hertel[+]. Some typical examples will be discussed such as e-He, e-H, e-Na, e-Ar, e-Kr, each case adding some complexity in the description, from fully coherent, via partially coherent with conservation of atomic reflection symmetry to processes with spin flip which do not necessarily conserve atomic reflection symmetry. A comparison of the various sets of experimental and theoretical data shows some interesting trends in particular for the alignment angle and the angular momentum transfer. Agreement is found mainly for small scattering angles 0, while some problems exist at large 0. We shall emphasise crucial situations for testing the theory more critically and also show that a polar plot of the linear polarisation components P_1+iP_2 (with 0 as a parameter) gives very interesting insights in the principle behaviour of various sets of data, ruling out some theoretical results quite clearly, while others deserve more stringent experimental tests. In summary: we have learned a lot so far but a lot still remains to be done in the future. We advocate a somewhat more coordinated effort to resolve the remaining discrepancies.

[+]H.W. Hermann and I.V. Hertel, Comm.At.Mol.Phys.12, 61 and 127 (1982)

ELECTRON SCATTERING ON HEAVY ATOMS*

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Electron scattering by heavy atoms has been studied both experimentally and theoretically for many years. Experimentally, not only can total and differential elastic and inelastic cross sections be measured, but the use of high resolution polarised electron and atom beams enable observables such as the spin polarisation, asymmetry functions and the Stokes' parameters to be determined. Theoretically, new developments in methods and computer programs have enabled the combined influence of resonances, electron exchange and relativistic effects, to be accurately included.

In this paper we present recent results for elastic and inelastic scattering of electrons by Cs, Hg, Tl and Pb targets using the relativistic R-matrix method[1]. These calculations include for the first time all the effects mentioned above within the framework of the Breit-Pauli Hamiltonian. The influence of electron correlation on resonances in e^- - Hg scattering and the role of the one-body spin orbit, mass correction and Darwin operators will be discussed.

Fig. 1 shows the influence of the Darwin term and the mass correction term on the spin polarisation function S_p and the asymmetry function S_A for the electron impact excitation of the $(6s6p)\,^3P_1$ state of Hg from the $(6s^2)\,^1S_0$ ground state. It can be seen that the additional terms in the Hamiltonian clearly change the results of an earlier R-matrix calculation[2,3], where only the spin-orbit interaction was included. The structure of the curves and the overall agreement with the experimental data[4] remains essentially unchanged. This indicates that other effects like core polarisation and electron correlation are also important and have to be taken into account for further improvement of the theoretical results.

Electron correlation on the $(6s6p^2)$-resonances in e^- - Hg scattering has been studied by including additional correlation functions in the R-matrix expansion. The most important change to the original R-matrix calculation[3,5] is a split in the energy positions of the $(6s6p^2)\,^2D$-resonances. This effect can be simulated by shifting the corresponding R-matrix poles and in fig. 2 we show the results of the integrated Stokes' parameter η_2/P_y, which describes the circular polarisation of the light emitted after excitation with traversally polarised electrons. The agreement with the experimental data[6] has clearly improved, a tendency which is also found for other observables which strongly depend on the position of these resonances.

The R-matrix calculations for e^- - Hg scattering will also be compared with recent DWBA results[7] and new experimental data of the Münster group.

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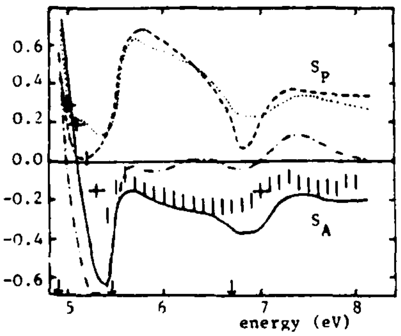

Fig. 1: Spin polarisation function S_p and scattering asymmetry function S_A for the $(6s^2)\,^1S$ ---> $(6s6p)\,^3P_1$ transition in Hg. Comparison of the old (—— and ---) and the new (.... and .-.-) R-matrix calculations (see text) with the experimental data (Bartschat et al 1981) for an electron scattering angle $\theta_e = 90^o$.

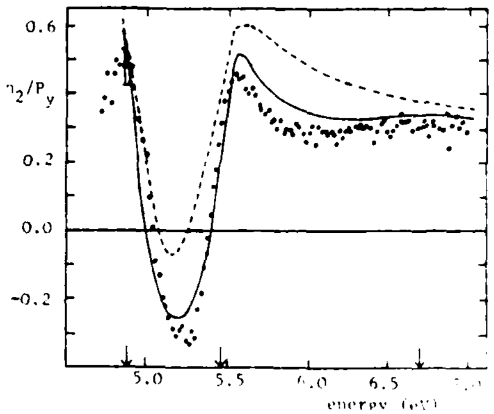

Fig. 2: Results for the integrated Stokes' parameter η_2/P_y in the old (----) and the new (——) R-matrix calculations (see text) compared with the experimental data of Wolcke et al (1983)

Electron-photon angular correlation parameters for Kr: $5S[3/2]_1^o\ ^1P_1$, $5S'[1/2]_1^o\ ^1P_1$, Xe $6S[3/2]_1^o\ ^3P_1$, $6S'[1/2]_1^o\ ^1P_1$ and H_2: C $^1\Pi_u$ excitation

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Electron-photon coincidence measurement between scattered electrons and emitted photons from decaying atoms (molecules) is a powerful tool for understanding the electron-atom (molecule) scattering processes. These experiments have brought valuable new informations into this field.[1] For heavy atoms, the spin-orbit coupling is strong and an appreciable anisotropy is expected for the photons emitted.[2,3] For molecules, the target rotation introduces a new feature.[4]

The angular correlation parameters (λ, χ and ε) for Kr: $5S[3/2]_1^o\ ^3P_1$, $5S'[1/2]_1^o\ ^1P_1$ and Xe: $6S[3/2]_1^o\ ^3P_1$, $6S'[1/2]_1^o\ ^1P_1$ excitations were measured at incident electron energies 40, 50, 60 and 80 eV for scattering angle up to 30°. Photons from excited states were detected by a VUV photomultiplier tube with MgF_2 window and CsI photocathode which covers the sensitive wavelength region of 115-200 nm. Due to the difficulty of the circular polarization measurement for VUV photons, the angular correlation parameter χ was determined instead of $\bar{\chi}$ and Δ. ($\cos\chi = \cos\bar{\chi}\cos\Delta$).[2,3] The photon detector can be rotated around the collision center from 40° to 140° in the azimuth angle $\phi = 3\pi/4$ and $\phi = \pi$ respectively. Combining these two measurements at each incident energy and each electron scattering angle, the parameters λ, χ and ε are determined.

Angular correlation measurement were also made for the H_2, C $^1\Pi_u$ excitation. Because of the molecular rotation, it is still necessary to perform measurement at two different azimuth angle.[4] Angular correlation parameters were determined at incident electron energies 30, 40 and 50 eV for scattering angle up to 15°.

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"Electron-Photon Coincidence Experiments Using Molecular Targets"

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Although the electron-photon coincidence technique provides one of the most sensitive tests of the electron impact excitation process and although it has been applied widely to atomic targets during the past ten years particularly for the study of simple L-S coupled systems such as He and H, very little progress has been made in applying it to molecules for a number of reasons. The problems are largely experimental, the basic theoretical formalism having been worked out by Blum and Jakubowicz [1] in 1978.

The first and major experimental difficulty is that of obtaining rotational resolution so that experimentally measured data can be related to such parameters as state multipoles in a reasonably simple way. Early measurements by the Windsor group[2,3,4] made no attempt to gain such rotational definition and so the measured Stokes parameters related to some combination of angular momentum states. Thus, they could not be analysed to give the same detailed information as had been possible with atomic excitation experiments. These early experiments did however reveal a surprising amount of coherence; (based on large non-zero values of the measured normalized Stokes parameters), suggesting that a more detailed investigation of the subject might prove fruitful.

The second experimental problem was one which was also common to most of the atomic experiments, namely that of circular polarization measurement in the V.U.V. spectral region. This meant that the critical Stokes parameter, which carried the information on the transfer of orbital angular momentum perpendicular to the scattering plane in the collision, was not measured.

The present paper presents data on two attempts to surmount these problems. In the first experiment[5], carried out at the Jet Propulsion Laboratory, a polarization-correlation study was made of the excitation of a single ro-vibrational level (v = 0, N = 1) of the $d^3\pi_u$ state of H_2. Since the emission of radiation (to v = 0, N=1 a $^3\Sigma_g$) occurs in the visible at 601.9 nm measurement of the circular polarization was not a problem. Rotational selectivity was achieved using a narrow-band line filter. In the second experiment carried out at the University of Windsor, a V.U.V. circular polarizer[6] has been used to extend the earlier data on the excitation of

H_2, C $^1\pi_u$. In this direct process significant amounts of circular polarization were observed at the larger electron scattering angles whereas in the excitation of the $d^3\pi_u$ state which proceeds via an exchange process no significant transfer of angular momentum, perpendicular to the scattering plane, occurred.

The problems involved in carrying out these measurements together with the interpretation and implication of the results already obtained, will be fully discussed at the Conference. Future directions in this field will be highlighted.

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SOME PHYSICS WITH STATE SELECTED SODIUM BEAMS

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- Abstract Unavailable -

COHERENCE AND CORRELATIONS IN ELECTRON COLLISIONS WITH METAL VAPOURS

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The measurement of the three components of the polarisation of radiation emitted normal to the scattering plane can be used to determine the coherence of the excitation of an atomic state. Normally it is expected that coherence is implied by the conditon $|P| = |$[1].

In the case of electron collisions with sodium, however, this procedure is complicated by the presence of unresolved hyperfine structure in the excited state which depolarises the decay radiation and makes $|P| \neq |$ regardless of the coherence of the excitation process. This problem can be overcome by invoking the Percival-Seaton hypothesis[2] and by factorising out the influence of the post collision loss of coherence. This defines the reduced degree of polarisation[3] $|\bar{P}|$. $|\bar{P}| = |$ is then the condition for coherent excitation for states with significant HFS.

$|\bar{P}|$ has been measured over a wide range of energies for forward angle scattering in the excitation of the 3^2P state in sodium. Results are presented which demonstrate that the excitation is coherent in this kinematic region. These results are used to show that the role of spin can be ignored for forward angle inelastic electron scattering from sodium in the energy range from 12.1eV to 100eV; that is our results demonstrate that the relationship[4] $a_o^s\, a_1^t = a_1^s\, a_o^t$ holds in this region.

The polarisation component P_4 of radiation emitted in the scattering plane has been measured for several electron energies. Following the prescription of Hermann and Hertel[5], these data can be compaired with the linear component out of the scattering plane P_1 to yield the spin flip cross section ρ_{oo}. We find that $\rho_{oo} = 0$ for energies and scattering angles where $|\bar{P}| = |$; that is the data are consistent.

Orientation and alignment parameters, deduced from the polarisation measurements, are compared with theoretical predictions. The possible extension of the present measurements to larger scattering angles is discussed and the consequences explored. Our results show clearly that there is a definite advantage to the use of the natural coordinate frame of Hermann and Hertel[5]. The present results are compared with those derived from the time reversed experiments of Hertel and collaborators[6].

An angular correlation for the excitation of the 3^2P state in sodium is presented. When the scattering parameters, deduced from these data, are compared with those derived from the polarised photon experiments, it is clear that the latter technique is preferable.

Finally the results of a polarised photon coincidence experiment in magnesium will be presented.

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APPLICATIONS OF STEPWISE EXCITATION TECHNIQUES TO POLARISATION CORRELATION AND SUPER-ELASTIC SCATTERING STUDIES OF ELECTRON-ATOM COLLISIONS

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During the past decade steady progress has been made in the application of laser techniques to electron-atom collision physics. Super-elastic scattering studies (1,2), the production of spin-polarised electron sources (3) and the use of stepwise excitation techniques (4) are examples of the application of lasers in this field, the latter topic being the major theme of this paper.

Stepwise excitation by a combination of electron and laser excitation provides information about the collision processes involved in the electron excitation step by intensity and polarisation measurements made on fluorescence emitted from stepwise excited atoms. Correlation measurements between inelastically scattered electrons and stepwise excited photons are also possible. These techniques provide some novel experimental methods for studying electron-atom collision processes. If laser excitation is used in the first step, information may be obtained about excited state collision parameters. The use of laser excitation in the second step provides new methods for studying the electron impact excitation of ground state atoms.

The high spectral resolution possible in the laser excitation step allows the fine and hyperfine structure of many atomic transitions to be resolved. This allows the effects of such structure on atomic collisions to be studied as in tests of the Percival-Seaton hypothesis or enables such effects to be experimentally eliminated in the measurement of atomic collision parameters. Other novel features occur because the laser radiation is polarised. Stepwise excitation experiments performed with different laser polarisations allow the sublevel populations of electron-impact excited states to be probed more completely than is possible with conventional methods, yielding information which has not previously been

accessible. Such an example is the recent measurement (4) of the partial total cross-sections of the 6^3P_2 metastable state of Hg using stepwise excitation techniques.

Stepwise excitation techniques provide new methods of investigating the electron-impact excitation of vacuum-ultraviolet transitions. Polarisation measurements which would be made on VUV lines in conventional experiments may in effect be made on longer wavelength lines using stepwise excitation techniques when appropriate excitation schemes exist.

Another type of stepwise excitation scheme will also be discussed which is an extension of existing super-elastic experiments through the use of stepwise excitation of atoms by two or more laser beams. Such experiments offer a means of accessing highly excited states which will enable detailed studies to be made of collisions between highly excited atoms and electrons.

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